erated LED chips which may enhance light extraction from the chips when compared to chips generated by scribing on a single side. Still further, the invention provides a wafer that has a scribe regions on each side of the substrate.

Various benefits are achieved over pre-existing techniques using the present invention. In a specific embodiment, the present invention provides for a method for singulation of thick c-plane GaN wafers into triangle-shaped LED chips defined by three equivalent m-plane oriented sidewalls. The m-plane is a natural break plane which easily cleaves, in the case of c-plane GaN wafers, and therefore, a singulation process involving breaking exclusively or predominately along a set of m-plane orientations will have a higher yield than a process involving breaking along both m-plane orientations and a-plane orientations. The invention provides for triangle-shaped chips characterized by improved light extraction when compared to conventional square- or rectangle-shaped chips, due to an increase in the per-pass probability of escape of in-plane emission, arising from a decrease in the probability of total internal reflection at the sidewalls. Additionally, in-plane standing optical modes in the case of square- or rectangle-shaped chips may be absent in the case of triangle-shaped chips.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram depicting a laser scribing process for an optical device;

FIG. **2** is a diagram depicting a breaking process for an optical device; and

FIG. **3** is a diagram of a separated surface of an optical device.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a side-view diagram depicting a laser scribing process for an optical device according to an embodiment of the present invention. In a specific embodiment, the LED wafer is laser-scribed within the 'scribe streets' on a first surface of the wafer, along one or more axes according to a specific embodiment. In other embodiments, the scribing can occur using a saw, a diamond scribe, a chemical etchant (with or without a photo-assisted component), reactive ion or plasma etchant or milling, or combinations, and the like. The scribe depth in the scribed regions on the first surface is typically 20-25% of the thickness of the LED wafer according to a specific embodiment. In other embodiments, the scribe depth can vary and have other dimension. In a specific embodiment, the scribe line also has a suitable width and length Of course, there can be other variations, modifications, and alternatives.

In a specific embodiment, the LED wafer is then flipped over, and is then laser-scribed within the 'scribe streets' on a second surface of the wafer, along one or more axes, taking care to ensure that the scribes on the second surface are aligned to be substantially overlying the scribes on the first side of the wafer. In a specific embodiment, the scribe depth in the scribed regions on the second surface is typically 20-25% of the thickness of the LED wafer The scribed LED wafer is then broken using an anvil breaker setup, such as the one further described below.

FIG. **2** is a simplified side-view diagram depicting a breaking process for an optical device according to an embodiment of the present invention. As shown, breaking occurs along the planes defined by two aligned scribed regions on the two opposing sides of the wafer. In a specific embodiment, the present method provides for the singulation of thick GaN wafers, thereby eliminating the need for expensive and time-consuming lapping and polishing steps in the LED fabrication process.

In a specific embodiment, the present method provides for the singulation of thick GaN wafers into individual LED chips with lateral chip dimensions that are significantly smaller than those enabled by standard single-sided scribe methods. In other embodiments, the present method provides higher process yields at the scribe and break process steps than conventional methods. Additionally, there is a reduced incidence of chip-outs, as well as doublets (pairs of chips that are not separated during the break step). In other embodiments, the scribed regions may induce surface roughening on the side-walls of the generated LED chips which may enhance light extraction from the chips when compared to chips generated by scribing on a single side.

FIG. **3** is a side-view diagram of a separated surface of an optical device according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims herein. One of ordinary skill in the art would recognize other variations, modifications, and alternatives. As shown, the separated surface demonstrates the present method.

In other embodiments, the method can also include other variations as described below.

1. The LED wafer may be a c-plane GaN wafer, m-plane GaN wafer, or a semipolar GaN wafer, or other single-crystalline wafer with an LED epitaxial structure overlying at least one surface of the wafer.

2. The LED wafer may be scribed on the two surfaces using a plurality of scribe methods, for example, laser scribing, diamond scribing, and sawing/dicing or others.

3. The scribe depth on one side of the LED wafer is between 0.5% and 99.5% of the thickness of the wafer.

4. The scribed regions may have continuous scribe lines, dashed scribe lines or dotted scribe lines. The scribed regions along axes may or may not intersect in the regions defined by intersecting 'scribe streets.'

5. Scribing may be performed along at least one 'scribe street' orientation on a first surface, and along at least one 'scribe street' orientation on the surface, such that at least two 'scribe street' orientations chosen are non-parallel.

6. The scribed LED wafer may be broken using a an anvil breaker, roller breaker or breaker bar.

While the above is a full description of the specific embodiments, various modifications, alternative constructions and equivalents may be used. The present specification describes specific surface orientations, but it would be recognized that any plane orientation can be used. The above description and illustrations should not be taken as limiting the scope of the present invention which is defined by the appended claims.

What is claimed is:

1. A method for separating individual die from a gallium and nitrogen containing substrate having a plurality of optical devices arranged in an array, the substrate member having a front side and a back side, the method comprising:

aligning a scribe device to scribe at least a street region on a portion of the front side between a first optical device and a second optical device;

forming a first scribe line on the street region between the first optical device and the second optical device;

forming a second scribe line on a backside portion of the substrate member and overlying the first scribe line while maintaining a thickness of the substrate member between the first scribe line and the second scribe line; and